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GROWTH ROOM TEMPERATURE CONTROL WITH WATER-SOURCE HEAT PUMPS

by

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SUMMARY:

Water-source heat pumps were used to accurately maintain insect growth room temperatures for year round production. A copper ground loop installed in a municipal drain acts as the heat source/heat sink. Programmable thermostats provide room temperatures within 1C° of setpoint.

KEYWORDS: Heat Pumps, Environmental chambers, Ground loop.

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INTRODUCTION

In order to develop and evaluate effective control measures for insect pests, researchers must be assured of a known and uniform infestation within their research plots. The Horticulture and Biology Section at Ridgetown College began rearing their own insects specifically the European Corn Borer for research purposes five years ago. At that time electric unit heaters and window air conditioners were used to maintain the desired air temperatures in a small clay-block building. Room air temperatures would fluctuate 3 to 4^{Co} from the desired air temperatures. In addition the thermostats had to be manually adjusted twice daily to simulate day/night temperature swings.

More space was required and a new rearing facility was planned. Water source heat pumps were felt to be a good means of providing improved temperature controls for these new insect growth rooms.

OBJECTIVE

To determine the performance and economics of using water-to-air heat pumps to provide environmental temperature control in eight insect rearing rooms for year round production.

TEST FACILITY

Ridgetown College set out in 1986 to modify half the upper floor of a former two storey chicken barn into eight growth rooms for insect rearing. The floor area of this section is approximately 13m x 13m with a ceiling height of 2.3m. The outside walls were restudded and insulated to R-20 with fiberglass batts. The ceiling insulation level was upgraded to R-30 again using batt insulation. A continuous vapour barrier was installed to prevent moisture movement into the insulation material. This area was subdivided into 8 rooms. The four small pupation rooms measure 2m wide by 5.5m long, and four oviposition rooms measuring 4.4m wide by 5.5. long. Two pupation and two oviposition rooms are on each side of a service hallway. Figure 1 shows the layout of these rooms. Partition walls between rooms were all insulated with R-12 fiberglass batts.

TABLE #1 ROOM FUNCTION & ENVIRONMENT

	SMALL ROOMS #1,4,5,8	LARGE ROOMS #2,3,6,7
PURPOSE	PUPATION - egg hatching, larvae feeding - pupation in cardboard rings, in feeding dishes	OVIPOSTION - cardboard rings placed into screened cages to allow adults to emerge - adults lay eggs which are used in research
ROOM LAYOUT	- shelves to support feeding dishes on both long walls	- screen cages stacked on floor up to 5 high
TEMP REQ'TS	- constant 23°C	- day temperature 26°C - night temperature 19°C
RELATIVE HUMIDITY	>85%	80%
LIGHTING	- continuous light	- 14 hours light - 10 hours night

The environmental control system for these growth rooms had to be able to do the following;

1. maintain accurate temperature controls automatically summer and winter.
2. be programmable to simulate day/night temperature fluctuations.
3. circulate air in the growth rooms to maintain temperature uniformity.
4. maintain high relative humidity levels in the growth rooms.

It was determined that water-to-air heat pumps with appropriate controls could fulfill all these requirements with the exception of maintaining high relative humidity in the rooms.

The system installed consists of water-to-air heat pumps, programmable thermostats, and a common ground loop. Eight one Ton heat pumps , WaterFurnace Model WXH012, were mounted horizontally from hangers on the ceiling, one per room. Rather than downsize the heat pumps for the smaller rooms, the same size units were installed throughout. The heat pumps supply the entire heating and cooling functions in these rooms with only an antiquated boiler, which heats the rest of the building as a backup heat source.

The supply and return loop pipes are situated in the attic above the service hallway. The heat pumps are hooked up to the loop supply and return lines in a reverse-return piping system. This is important to ensure that uniform flow is obtained through each heat pump. Flow rate through each unit is approximately 0.2 L/s. Figure 2 shows the layout for reverse-return piping system.

A single loop circulation pump situated on the first floor, pumps 1.5L/s of a water and methanol mixture through the loop. The loop circulation pump is interlocked with the heat pumps so that the pump is activated when any of the thermostats call for heating or cooling. The loop liquid is ciculated through all the heat pumps whenever the loop pump is on.

The ground loop is a closed system. The location of this loop is unique in that it is not installed in the soil but rather in the bottom of an open municipal drainage ditch, passing within 50 metres of the insect rearing facility. The shallow ditch is approximately 4 metres wide with water flowing year round. Since this municipal drain falls under the jurisdiction of The Township of Howard, no alterations could be made to the drain without their approval. The township council was approached and approval was obtained to install the loop in this municipal drain. They were confident that this loop would in no way impede the flow of water through this drain. Their only stipulation was that it would be the College's responsibility to remove the loop from the drain if and when cleanout of the drain was necessary.

Since this near ideal heat sink/heat source was so close, it was decided that a copper ground loop would involve less pipe resulting in reduced cost. The copper pipe would also tend to sink to the bottom of the ditch, whereas plastic might require anchoring to stay submerged. The ground loop consists of 200m of 25mm diameter type "L" copper pipe. This is arranged as four parallel 50m lengths connected to a header at both ends. All copper joints in this loop were silver soldered. The loop was preassembled on the bank of the drainage ditch and carried into the ditch, setting it in place on the bottom of the ditch. The loop layout in the municipal drain can be seen in Figure 1. The loop at present is sitting in the muck at the bottom of the ditch with approximately 0.5m of water cover.

Polybutylene pipe, 75mm in diameter, was used as the supply and return lines from the loop as well as throughout the building. All plastic joints were fusion welded to minimize the chances of any leaks. For freeze protection the loop solution consists of a mixture of 20% methanol, 80% water as well as a stabilizing agent to prevent; algae and bacterial growth, and scale formation.

Since individual room temperature control is desired, each heat pump is being controlled by its own thermostat. The thermostats are Enerstat model HP 1 programmable thermostats, installed in the hallway and connected to a remote temperature sensor inside the room. With all the thermostats in the hallway, room temperatures can be checked at a glance on the digital readouts. These

thermostats were specifically designed for heat pumps and are capable of automatic changeover from heating to cooling or vice versa. A built in time delay allows for refrigerant pressure equilization when switching from heating to cooling or vice versa.

The thermostats are programable on a 5-1-1 day schedule. Four different temperature regimes can be selected for each of; the weekday group, Saturday, and Sunday. For each program you select the starting time, heating temperature and cooling temperature. The minimum differential possible between heating and cooling setpoints is 2C°. The heating temperature is set 1C° lower than the desired room temperature with cooling temperature set 1C° higher than the desired room temperature. The thermostats then automatically regulate the heating or cooling mode maintaining desired room air temperatures. The thermostats are removable from the wall mounting plate allowing detailed programming to be completed elsewhere. Battery backup maintains the program in memory in the event of thermostat removal or power interruption. Programming buttons can also be locked out with movement of a dip switch.

OBSERVATIONS

The system has been working for 3 years. In that time the heat pumps have functioned very well, providing temperature control, better than expected.

With heating and cooling setpoints set at ±1C° from the desired room temperature, the heat pumps will maintain room air temperature at ±1C° of the setpoint. Figure 3 shows room air temperature in an oviposition the room with continuous heat pump fan operation. Figure 4 is the same room with intermittent fan operation. Continuous or intermittent fan operation can be selected with a button on the thermostat. In the intermittent mode the fan is only on when the heat pump compressor is running. The number of times the heat pump came on, can almost be counted on Figure 4. The room temperatures move up and down showing the change from day to night temperature as programmed.

Figure 5 shows the temperature and relative humidity levels in an oviposition room. It is obvious that relative humidity levels do not remain close to the desired 85% relative humidity. The heat pumps dehumidify the air drastically when the room is being cooled for night time conditions. An additional drum type humidifier was then used to add moisture to the air.

Fresh air is necessary for the proper growth and reproduction of insects. An insulated plenum above the service hallway is pressurized with outside air by means of a centrifugal fan. Flexible 100mm diameter dryer vent pipe ducts this fresh air from the duct to a plastic dryer vent mounted flush to the ceiling in each room. These vents are pointed towards the return air opening in the heat pump. In this way the outside air is mixed with room air and distributed throughout the room by the blower. The conditioned air is blown into the room directly from the heat pump without any ducting. This air then circulated fairly uniformly throughout the rooms. Each heat pump blower moves approximately 190 L/s of air. Adjustable louvres on the hall wall of each room, control the exhaust air from the room into the hallway.

Air flows were measured using an Alnor Balometer. The fresh air ventilation rates ranged from 12L/sec. to 20L/sec. for each room. The importance of this fresh air became drastically apparent when adult insects started dying sooner than expected. The cause was traced to the fresh air dryer vent flap having been jammed shut. When the flap was opened, mortality ceased.

A kilowatthour meter was installed to measure the electrical energy used by the heat pumps and loop circulation pump. The water temperature in the ditch fluctuates from a low of 7°C to a high of 34°C during the year. With all heat pumps operational the difference in temperature from loop entering to loop leaving the building is 3C° in heating and 3C° in the cooling mode.

ECONOMICS

Cost of the system (MARCH 1986)

Eight 1 Ton water-to-air heat pumps	$ 14,700
Loop circulation pump	500
Copper ground loop (200m, 25mm diameter)	1,400
Eight programmable thermostats with remote sensors	1,440
Trenching	300
Polyethylene pipe, fittings, etc.	1,716
Labour	3,640
TOTAL	$ 23,696

Fixed cost of the system = $\frac{\$23,696}{8 \text{ Rooms}}$ = $ 2,962 per room

Operating Costs: Electricity: $0.06kWh.

Heating: Avg. 95 kWh/day for the whole system operating at ambient air temperature of 3°C.

∴ Cost per room/day = $\frac{95}{8}$ x $0.065

= $0.71 per room/day

Cooling: Average 120 kWh/day for whole system operating at ambient air temperatures of 27°C.

∴ Cost per room per day = $\frac{120}{8}$ x $0.06

= $0.90 per room/day

Operating costs of the heat pump system range from $0.71 per room per day for heating at -3°C to $0.90 per room per day at 27°C for cooling.

CONCLUSIONS

1. This heat pump system has worked very well for the past 3 years maintaining the room air temperature to within ±1C° of the setpoint.

2. Since each room is totally independent, each can be operated at its own temperature regime. This means that one room can be kept at a significantly higher or lower temperature as desired.

3. Programmable thermostats can be used to simulate day/night temperature swings with up to four temperature settings per day. Continuous or intermittent fan operation can also be selected on the thermostat.

4. Humidity control is a problem when using these heat pumps for temperature control. In the cooling mode the heat pumps dehumidify the air. Additional moisture has to be added to this air to maintain relative humidity at 85% or greater.

MECHANICAL PROBLEMS

A few minor problems have shown up. The use of non-shielded remote sensor cable caused problems in maintaining proper temperatures in the rooms. Induced voltage from nearby electrical wiring caused the thermostat to sense inaccurate room air temperatures. Shielded remote sensor cable was installed and the desired temperatures were again maintained.

The lockout relays on two of the heat pumps have been replaced. It is unsure whether these were defective or merely malfunctioned due to machine vibration.

At the start of this project it became apparent that filtering of the return air was important. The adult insect moths shed scales from their wings which clogged the fin coils of the heat pump. Without filters the coil fins were becoming clogged reducing airflow through the coils and the compressor shut down. The problem was corrected by installing washable filters on each heat pump.

The only serious problem with the loop has been human. The polybutylene return line in the ditch was punctured inadvertently by a sickle, while harvesting water cress growing in the ditch. Repairs were quickly made and the system was returned to working condition.

OTHER USES

In addition to rearing European Corn Borers the growth rooms have been used for many other purposes.

Some of these include:

- seed germination and vigour ratings of vegetable seeds at various temperature regimes.
- alfalfa leaf cutter bee rearing.
- egg hatching of Colorado potato beetles.
- corn root worm rearing.

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Mr. Gene Hoste, Horticulture & Biology Section, Ridgetown College, for drawing attention to any problems, with the heat pump system, to our attention.

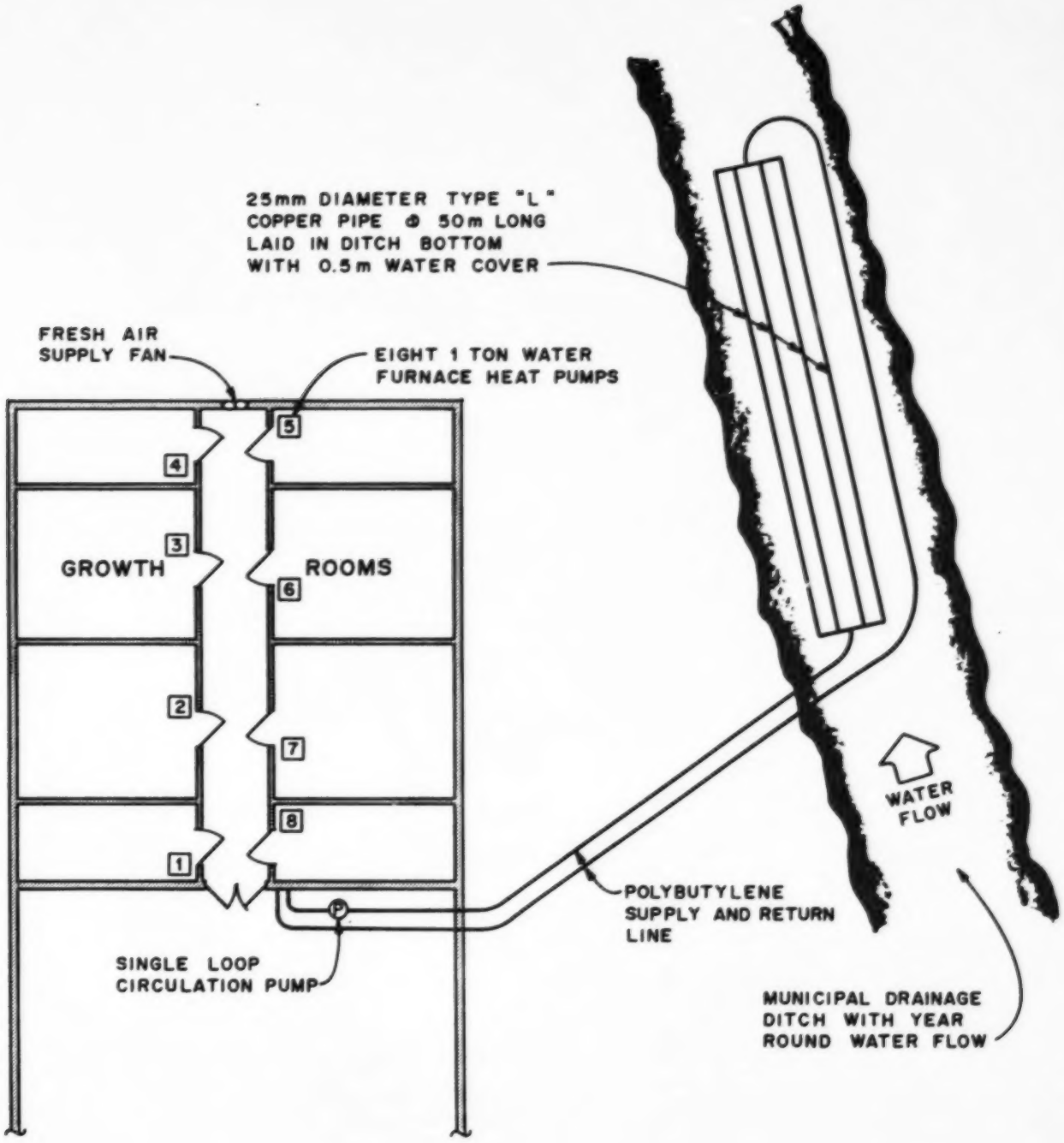

FIGURE 1 — SCHEMATIC OF RIDGETOWN COLLEGE GROWTH ROOMS AND GROUND LOOP LAYOUT

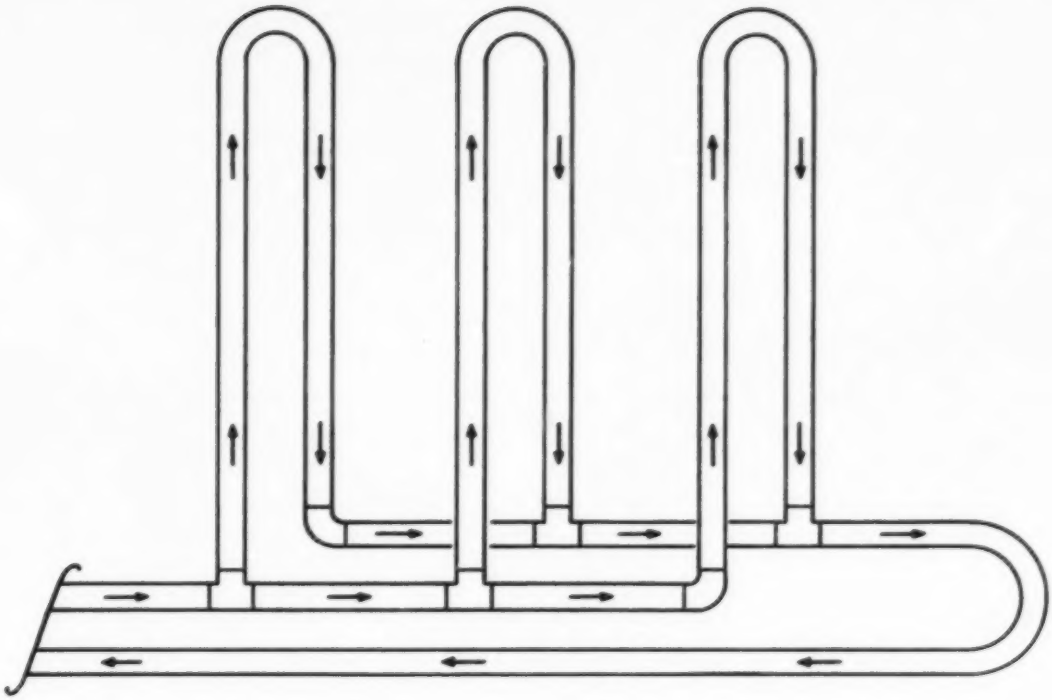

FIGURE 2 — REVERSE-RETURN PIPING SYSTEM

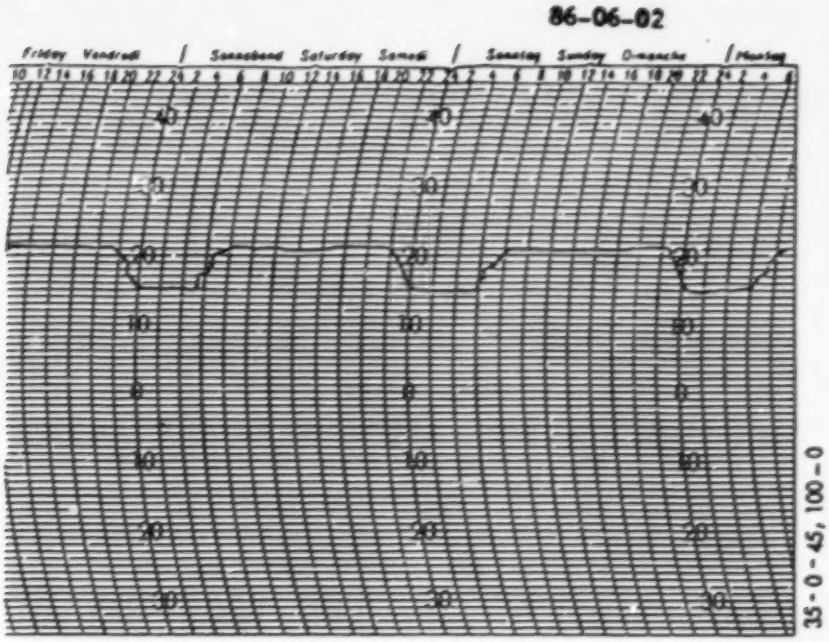

FIGURE 3. ROOM AIR TEMPERATURE WITH CONTINUOUS FAN OPERATION

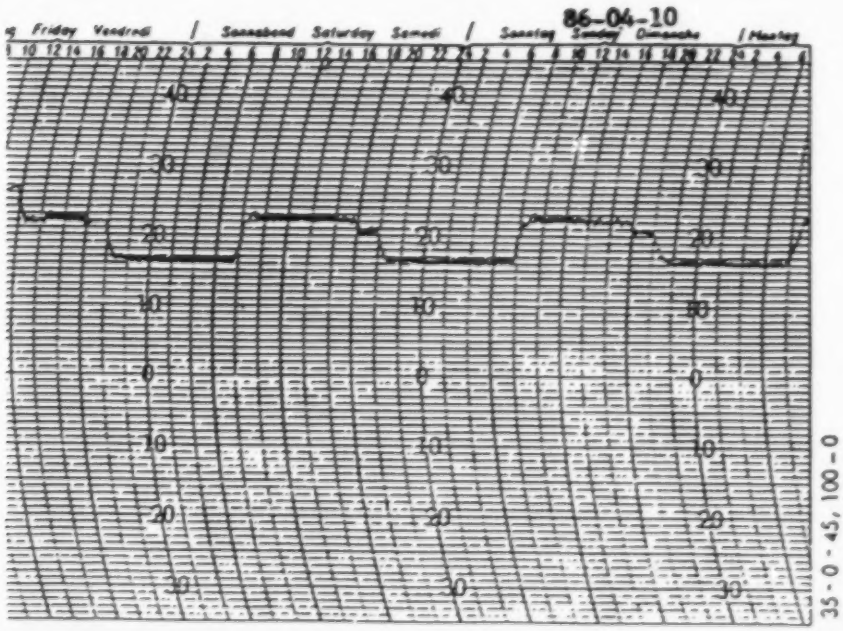

FIGURE 4. ROOM AIR TEMPERATURE WITH INTERMITTENT FAN OPERATION (FAN ON ONLY WHEN HEAT PUMP IS RUNNING)

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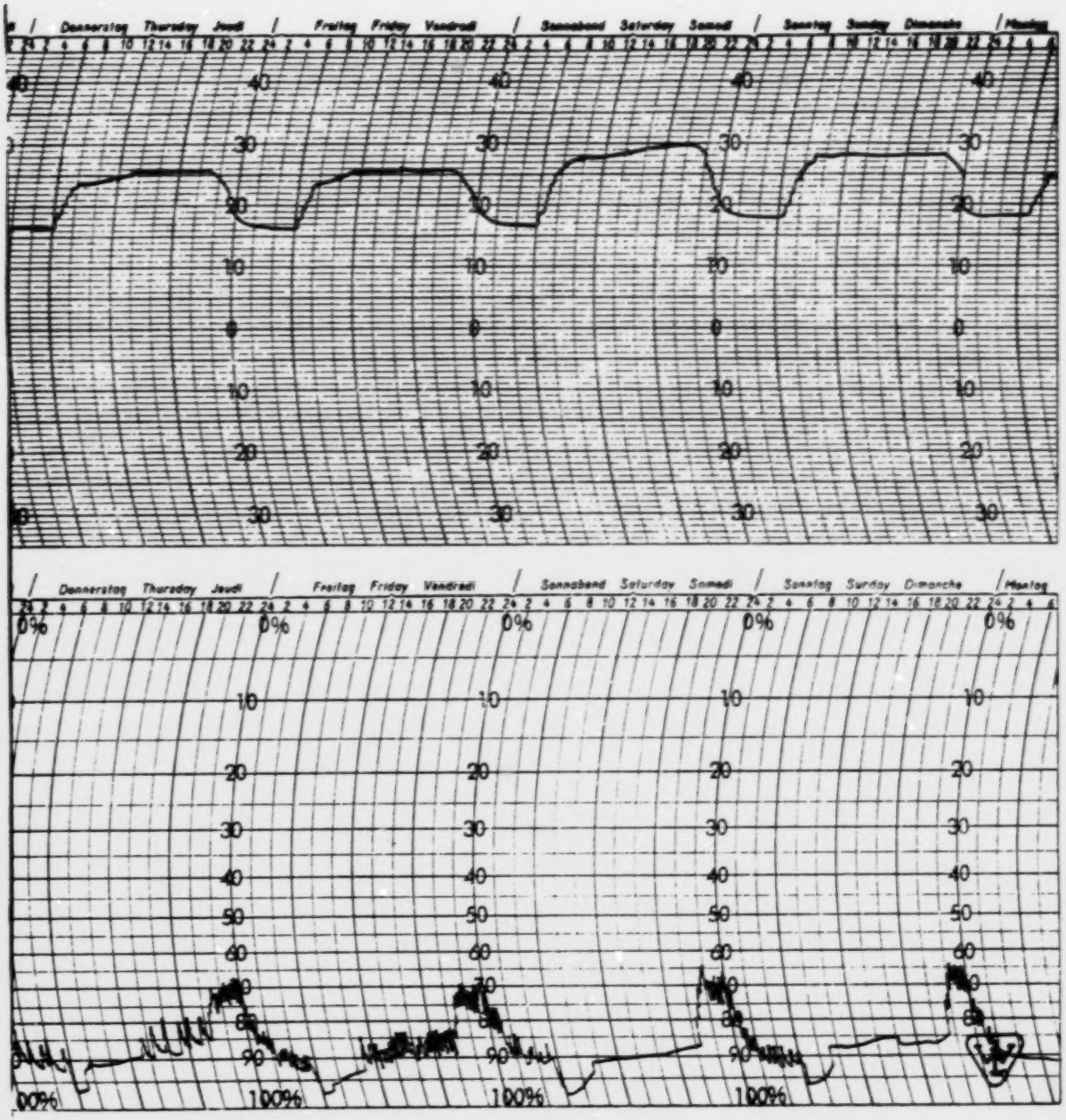

FIGURE 5. TEMPERATURE AND RELATIVE HUMIDITY LEVELS IN ROOM #2